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# **ENVIRONMENTAL CHARACTERISTICS OF RESERVOIR SYSTEMS IN THE CZECH REPUBLIC**

FINAL TECHNICAL REPORT

BY

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## REPORT DOCUMENTATION PAGE

Title: Environmental Characteristics of Reservoir Systems in the Czech Republic

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Abstract: The sustainable use of reservoirs needs to be based on the concept of watershed-level management. This requires complex information on natural conditions, land use, sources of pollution, and socio-economic conditions within the watershed area and on the physical, chemical and biological structure of the reservoir ecosystem. The aims of this work were to (i) collect data sets from watershed-reservoir systems in the Czech Republic that can serve this purpose and (ii) indicate the major factors influencing reservoir- and stream-water quality. A geographic information system (ArchView3.1) has been used to organize watershed data on terrain morphology, river network, standing waters, land cover, land management, soil characteristics, hydrogeology, water management, point sources of pollution discharges to water courses, and monitoring stations of meteorology, stream hydrology, and water chemistry. Additional attribute data for more detailed descriptions of selected watershed characteristics and for long-term data records have been collected in the spreadsheet format (MS Excel 97). Data from three watershed-reservoir systems have been collected: the Zelivka, Rimov, and Lipno. All of them represent systems with the main reservoir at their lowest parts. Their watershed areas are 1178, 489, and 948 square kilometers and the values of mean water residence time 475, 90, and 270 days, respectively. The reservoirs are of storage type and serve multiple purposes, e.g. raw water withdrawal for drinking water treatment, flow augmentation, and flood protection (all three of them), hydropower (Lipno, Rimov), and recreation (Lipno). Their water quality and their structure of aquatic ecosystem are largely influenced by municipal wastewater discharges into the tributaries or directly into the water body (Lipno), agricultural use of the catchment

(Zelivka, Rimov), and the system of pool operation (surface level fluctuation and depth of outlets).

Keywords: Reservoir, Watershed, Reservoir Management, Water Quality, Land Use, Point and Diffuse Sources of Pollution

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## Introduction

The sustainable use of reservoirs needs to be based on the concept of watershed-level management. This requires complex information on natural conditions, land use, sources of pollution, and socio-economic conditions within the watershed area and on the physical, chemical and biological structure of the reservoir ecosystem. The aims of this work were to (i) collect data sets from watershed-reservoir systems in the Czech Republic that can serve this purpose and (ii) indicate the major factors influencing reservoir and stream water quality.

## 1. Methods

### 1.1. Localities

The three watershed-reservoir systems, Zelivka, Rimov, and Lipno, are situated in the European ecoregion of Central Highlands and belongs to the Elbe basin (Fig. 1).

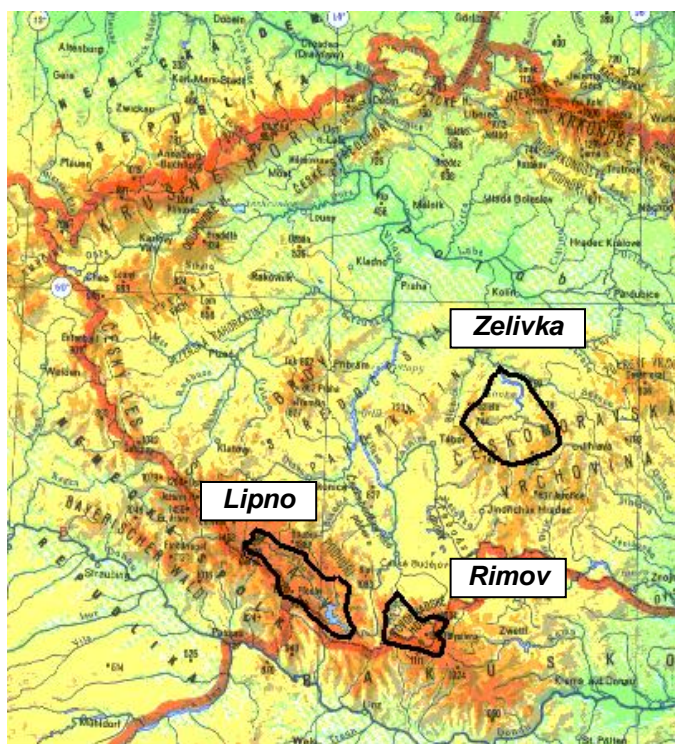


Figure 1. Locality of the watershed-reservoir systems

### 1.1.1. The Zelivka

The Zelivka River is a middle size river with maximum flow after the snowmelt in March and April and minimum flow in the autumn. The mean annual discharge near the outlet is  $6.8 \text{ m}^3 \text{ s}^{-1}$ . The river was dammed at its lower reach in 1971 to construct the Zelivka Reservoir. Since the 1980's, this reservoir has become the most important source of drinking water for more than 1 million inhabitants of the capital of Prague. Three pre-reservoirs are situated at the largest tributaries of the main reservoir. Major characteristics of Zelivka Reservoir and its pre-reservoir are in Table 1.

Table 1. Characteristics of Zelivka Reservoir and its pre-reservoirs

Characteristic	Zelivka		Sedlice	Trnavka	Nemcice
	max.*	min.*			
Starting year of filling	1971		1927	1981	1974
Altitude, m a.s.l.	377.0	343.3	449.0	414.5	386.2
Volume, $10^6 \text{ m}^3$	267	23	2.3	1.03	0.20
Surface area, $10^6 \text{ m}^2$	14.3	2.3	0.406	1.03	0.85
Mean / Maximum depth, m	19 / 53	9 / 19.5	5.7 / 15	6.3 / 11	4.3 / 8
Length, km	38	12	3	6	1.3
Catchment area, $\text{km}^2$	1,178		411	340	82
Mean flow (1951-1994), $\text{m}^3 \text{ s}^{-1}$	6.52		2.65	2.28	0.44
Water residence time, d	475	33	10	33	22

\* values at the maximum and minimum water levels of the reservoir storage volume

Water quality in Zelivka Reservoir has periodically deteriorated due to high nitrate concentrations caused by nitrate leaching from farmland and due to an excessive growth of phytoplankton proliferating on high phosphorus loads from municipal sources.

The bedrock of the Zelivka basin is formed by nutrient-poor rocks - paragneiss and mica-schist. Soils are mostly Dystric Cambisol and Eutric Gleysol (pH 3.8 to 4.2) with 17, 57 and 26% clay, silt and sand fractions, respectively. The main land use is intensive agriculture with cereal production and breeding of cattle, pigs, and poultry. The fertilization of arable land dropped by about 35% in the early 1990's, however, no corresponding



decrease of the nitrate concentration in streams has been observed. Forests are cultural, mostly coniferous with the dominance of spruce.

The human population in the catchment is ~53,000. Approximately one half of the population lives in towns and villages with more than 500 inhabitants. Waste waters from these municipalities are purified in secondary treatment plants, with an enhanced phosphorus removal technology at the two largest towns. The rest of the population, living in smaller villages and scattered dwellings disposes their sewage in septic tanks.

General catchment information are in Table 2. An analysis of water quality issues in the Zelivka watershed-reservoir system are given by Hejzlar et al. (1996).

Table 2. The comparison of watersheds.

Characteristic	Zelivka	Rimov	Lipno
Watershed Area, km <sup>2</sup>	1,189	489	948
Elevation Range, m a. s. l.	318-765	442-1,111	705-1,362
Mean anual rainfall, mm	669	772	884
Specific run-off, mm	173	280	440
Soils	dystic cambisol, eutric gleysol	dystic cambisol	spodo-dystic cambisol, deep podzol, gleysol, peats
Arable Land, %	50	32	3
Grassland, %	13	19	24
Forest, %	29	43	67
Open Water, %	1.8	0.6	4.7
Population density, person km <sup>-2</sup>	45	35	6 (35*)
Towns with over 500 inhabitants	14	4	7

\* with recreants during July-August

### 1.1.2. *The Rimov*

Rimov Reservoir is situated on the Malse River, 21.9 km upstream from its confluence with the Vltava River. The mean annual discharge at the Rimov Reservoir dam is 4.43 m<sup>3</sup> s<sup>-1</sup>.

The watershed area is situated at the border of the Czech Republic and Austria and its main characteristics are in Table 2. The bedrock is formed by weathered paragneiss, diorite and

granite. Most soils are Dystric Cambisol and mountainous podzols of acidic character ( $\text{pH} < 4.5$ ). About 32% of the catchment is used as arable land, 19% as meadows, 43% for forestry, and 2% are urbanised areas.

Římov Reservoir is a dimictic reservoir created in 1978 by damming of the Malše River. The main purpose is drinking water supply and flow maintenance; of a lesser importance is hydropower production. At maximum operation level (470.65 meters above sea level (m a.s.l.)), Římov Reservoir has a volume of  $32.1 \times 10^6 \text{ m}^3$  and a surface area of  $2.03 \times 10^6 \text{ m}^2$ . This 13-km long waterbody has a mean depth of 16 m and a maximum depth of 43 m. Most of the water enters the reservoir via its main tributary, the Malše, which drains 93% of the reservoir basin. The dam is equipped with multilevel outlet and withdrawal structures. The outflow usually occurs from upper layers during summer to maintain warm water downstream from the dam for recreation purposes, whereas releases occur from lower outlets between the autumnal to spring circulation periods. The raw water for the drinking water treatment plant ( $1.1$  to  $1.7 \text{ m}^3 \text{ s}^{-1}$ ) can be withdrawn from 5 intakes between 438.8 and 463.5 m a.s.l. (depths – 7 to 20 m). More information about the reservoir see can be found in Hejzlar and Straškraba (1989) and Komárková and Hejzlar (1996).

### 1.1.3. *The Lipno*

Lipno reservoir was built by damming the Vltava River at its 330<sup>th</sup> km upstream from the confluence with the Elbe River, which is ~76 km downstream from the Vltava River spring. The dam was finished and the reservoir started to fill in 1958. The reservoir serves multiple purposes, i.e. flow augmentation, hydropower, industrial and drinking water supply, flood protection, downstream river-ice problems alleviation, recreation and water sports, sport fisheries, and sailing. Main hydrological, morphological, and operational characteristics of

the reservoir are in Tab. 3. More detailed information on Lipno Reservoir water chemistry and biology is given by Brandl (1973a,b)

Table 3. Main characteristics of Lipno Reservoir

Maximum pool elevation	726.00 m a.s.l.
Permissible pool fluctuation range during V-XI	716.50 - 725.75 m a.s.l.
Permissible pool fluctuation range during XII-IV	716.50 - 725.30 m a.s.l.
Total controllable volume	$309.5 \times 10^6 \text{ m}^3$
Volume at surface level at 725.75 m a.s.l.	$297.4 \times 10^6 \text{ m}^3$
Volume at surface level at 725.30 m a.s.l.	$276.3 \times 10^6 \text{ m}^3$
Maximum backwater area	$48.7 \text{ km}^2$
Backwater area at surface level at 725.75 m a.s.l.	$47.7 \text{ km}^2$
Backwater area at surface level at 725.30 m a.s.l.	$46.0 \text{ km}^2$
Maximum depth	21.5 m
Mean depth: maximum; during V-XI; during XII-IV	6,4 m; 6,2 m; 6,0 m
Mean discharge at the dam profile (1931-1960)	$13.1 \text{ m}^3 \text{ s}^{-1}$
Water residence time	270 d

The watershed (Tab. 2) is situated into the mountainous and sub-mountainous parts of the Bohemian Forest (syn. Sumava Mountains). The mean elevation of the watershed is 982 m a.s.l. The bedrock is formed with gneisses and migmatites in the northern part, and with granitic rocks in the southern and south-western parts. Spodosol, cambisol, mountainous podzols, undeveloped organic soils, and gleysols and peats (in the stream valleys) are the most common soil types.

## 1.2. Data organization

Two types of data are provided: Geographical (Maps) and Attribute data, for a number of themes. The themes are listed in Tab. 4 along with the naming convention for the data filenames:

Table 4. List of Themes. (ZEL, RIM, and LIP abbreviations are commonly used instead of XXX for the Zelivka, Rimov, and Lipno watershed-reservoir systems, respectively.)

Theme	Map Data	Attribute Data
Digital elevation model (DEM)	XXX_DEM	-
River Network	XXX_Rivers	XXX_Rivers
Catchment Data	XXX_Catchment	XXX_Catchment
Land Cover	XXX_LandCover	XXX_LandCover
Land Management	XXX_LandManagement	XXX_LandManagement
Soil Textural	XXX_Soil	XXX_Soil
Soil Hydrogeological	XXX_SoilHydrogeological	XXX_SoilHydrogeological
Aquifers	XXX_Aquifer	XXX_Aquifer_Groundwater
Groundwater	XXX_Groundwater	XXX_Aquifer_Groundwater
Water Management	XXX_WaterManagement	XXX_WaterManagement
Administrative Data	XXX_Administrative	XXX_Administrative
Agricultural Sources	XXX_AgriSources	XXX_PointSources
Direct Discharge sources	XXX_DDSources	XXX_PointSources
WWTP Sources	XXX_WWTPSources	XXX_PointSources
Weather Monitoring Stations	XXX_Stations	XXX_Stations1-Weather
Ground Water Monitoring Stations	XXX_Stations	XXX_Stations2-Groundwater
Runoff Monitoring Stations	XXX_Stations	XXX_Stations3-SWFlow
Surface Water Monitoring Stations	XXX_Stations	XXX_Stations4-SWMeasures
Reservoir Monitoring Stations	XXX_Stations	XXX_Stations5-Reservoir

### 1.2.1. Maps

Map data files are provided in the following formats : ESRI Grid, ESRI Shapefile, and ASCII-Raster file. The geographical data are in two Projection/Coordinate System, i.e. WGS84 and S-JTSK, the most commonly used system in the Czech Republic.

### 1.2.2. Attribute data

The attribute data have been collected in the Microsoft Excel Workbook (XLS) format. Templates have been designed and are provided for filling based on the set of templates used by the EUROHARP Data Exchange protocol (Bouraoui F., Van Liedekerke M., and Nogueira A. 2002, unpublished; <http://www.euroharp.org/>). Each template consists of many worksheets, the first one being an Index giving an overview of the parameters

included in the remaining worksheets. A compilation of all these indexes is given in the Interim Report. Some sheets within the Workbook contain lookup tables from which type codes have to be selected. Generally the name of these sheets is post-fixed with the 'Types' string (e.g. CropTypes in the LandManagement workbook). For the convenience of the user hyperlinks have been included in each sheet. The links on the index page point to the main entry of each parameter. The links within other worksheets point to lookup data helping in identifying the expected information. For instance in the LandManagement.xls in the CatchmentCrop worksheet there is a CropType ID Hyperlink to the CropTypes worksheet. Additionally, within each worksheet, tooltip comments are supplied with all parameters, clarifying their meaning, units and where applicable time resolution.

Non value tokens: Whenever a value could not be provided one of the following codes was used:

#NAV# - Not Available

#BDL# - Not detectable – Below Detection Limit

#UNK# - Available but unknown

#MIS# - Missing Values – Because something went wrong.

The workbook data files are accompanied by text files which includes comments on the data in the data file (for instance information about measuring methods, etc).The basename is the same as the workbook to which it refers.

## 2. Description of available data

### 2.1. The Zelivka

The list of themes and the corresponding data files from the Zelivka watershed-reservoir system is in Tab. 5. The data files indicated in Tab. 5 are supplied on the compact disc that is attached to this report. Brief comments are provided for the content of data files within the next text.

Table 5. List of themes and data files from the Zelivka watershed-reservoir system.

Theme	Map Data WGS84 (\\ZE\WGS84)	Map Data JTSK (\\ZE\JTSK)	Attribute Data (\\ZE\Attrib)
Projection/Coordinate System	-	-	ZEL_Projection
DEM	CZZ_DEM	DEM_rastry	-
River Network	CZZ_Rivers	toky	CZZ_Rivers
Catchment Data	CZZ_Catchment	rozvodio	CZZ_Catchment
Land Cover	CZZ_LandCover CZZ_LandCoverLakes	landifo, landspoj, landpovo, landkata, nadrzeo	CZZ_LandCover
Land Management	-	-	CZZ_LandManagement
Soil Textural	CZZ_Soil	pudaz	CZZ_Soil
Soil Hydrogeological	CZZ_SoilHydrogeological2	rozvodig	CZZ_SoilHydrogeological
Aquifers	CZZ_Aquifer	transmiso	CZZ_Aquifer_Groundwater
Groundwater	CZZ_Groundwaterizob, CZZ_Groundwaterizoh	izobat, izohyps	CZZ_Aquifer_Groundwater
Water Management	CZZ_WaterManagement, CZZ_WaterManDrain2	watrego, meliofino	CZZ_WaterManagement, CZZ_WaterManStrategy, ZEL_PoolOperation
Administrative Data	CZZ_Administrative	katastro, katastrod	CZZ_Administrative
Agricultural Sources	CZZ_AgriSources	bodzdrojo	CZZ_PointSources
Direct Discharge Sources	CZZ_DDSources	bodzdrojo	CZZ_PointSources
WWTP Sources	CZZ_WWTPSources	bodzdrojo	CZZ_PointSources
Weather Monitoring Stations	CZZ_WeathetStations	meteopro	ZEL_Stations1-Weather

Theme	Map Data WGS84 (\\ZE\WGS84)	Map Data JTSK (\\ZE\JTSK)	Attribute Data (\\ZE\Attrib)
Surface Water Monitoring Stations	CZZ_SWStations	odbery01w	ZEL_Stations3-SWFlow ZEL_Stations4-SWMeasures ZEL_Stations5-Reservoir
Ground Water Monitoring Stations	CZZ_GWStations	odbery01w	ZEL_Stations2-Groundwater
Long Term Runoff Monitoring Stations	CZZ_RunoffStations	odbery01w	ZEL_Stations3-SWFlow
Subcatchments according to SWStations	CZZ_StationsSubcatchment	rozvodi	-
Point Localization of Municipalities	-	obcebodo, sildazelo	-
Point Localization of Reservoirs	-	nadrzbodo	-
Buffer Zone around Watershed	CZZ_CatchmentBuf	buffero	-

### 2.1.1. Watershed morphology and river network

The Zelivka watershed can be characterized as an upland plateau with deeply incised valleys of the Zelivka River and its main tributaries in their lower reaches (\\CZZ\_DEM, \\DEM\_rastry; Fig. 2).

Seven major ('backbone') water courses (CZZ\_Rivers.\*, toky.\*) were distinguished in the watershed. The water courses were cut into more than two thousand segments that were provided with mean depth, width, and order according to Strahler.

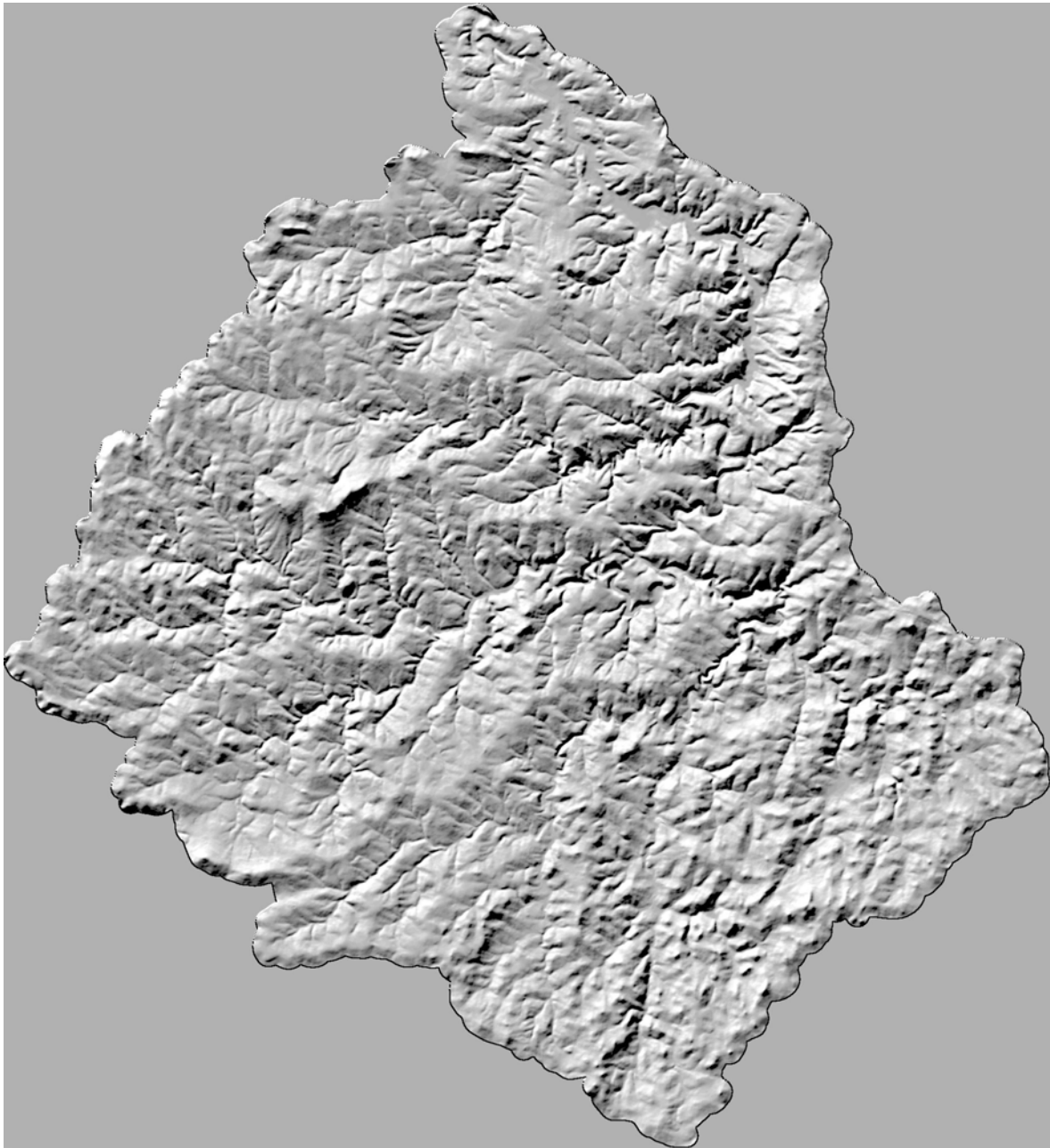


Figure 2. Shadow-portrayed terrain surface of the Zelivka watershed.



### 2.1.2. *Climate*

Four stations were selected to represent different parts of the Zelivka catchment (see figure in file CZZ\_Stations-3.jpg and files CZZ\_WeatherStations.\*, meteopro.\*, ZEL\_Stations1-Weather.\*). The data are technical data sets calculated by the Czech Hydrometeorological Institute, Prague, from several stations in the region. If there were any periods of missing data, they were interpolated from surrounding stations within the radius of 30 km for precipitation, temperature, and wind speed, 40 km for relative humidity, and 90 km for cloudiness. The station representative for the region of Zelivka Reservoir (Station 1) gives parameters that are needed for reservoir modeling with CE-QUAL-W2, i.e. rainfall, temperature, humidity, wind speed, and cloudiness. Daily values of rainfall and mean temperature are given for the other stations. The data sets contain continuous daily data from 1981 to 2001.

### 2.1.3. *Geology, soils, and hydrology*

The whole Zelivka catchment is geologically homogeneous and belongs to the Bohemian Massif - Moldanubian unit. The bedrock is formed by highly metamorphosed schists, gneiss, amphibolite, and lenses of serpentinitised peridotite at most areas. Only at the highest parts, at the watershed border, there are also granitic rocks (mostly Cadomian). The geological age is Lower Paleozoic – Proterozoic.

Fifteen soil types were classified in the Zelivka watershed (CZZ\_Soil.\*, CZZ\_SoilHydrogeological.\*, pudaz.\*, rozvodig.\*) and their basic textural and chemical properties given. The most common soil types are cambisols and gleyosols (close to water courses).

Aquifers in the Zelivka watershed are shallow. The layers of weathered parent rocks are commonly 2 to 6 m thick at maximum. If there is groundwater in deeper layers it is of the fissure origin. Maps of the groundwater depth (CZZ\_Groundwaterizob.\* (izobat.\*))

CZZ\_Groundwaterizoh.\* (izohyps.\*) – groundwater depth isolines and groundwater altitude isolines, respectively; CZZ\_Aquifer\_Groundwater.\*) were created by interpolation and generalization from the hydrogeologic survey of the catchment (J. Hejnak, unpublished reports from 1994–2000).

#### *2.1.4. Land use and administrative data*

Five land cover categories could be distinguished from the LANDSAT-TM image: lake (=all stagnant water surfaces), forest, arable land, grassland, and urban with industrial areas (CZZ\_LandCover.\*, CZZ\_LandCoverLakes.\*, landifo.\*, landspoj.\*, landpovo.\*, landkata.\*, nadrbzodo.\*, nadrzeo.\*). Summary of agricultural use of the watershed is given in the files 'Catchment.\*'. The data are related to the period between 1988 to 2000.

The administrative data (CZZ\_Administrative.\*, kaatastro.\*, katastrodo.\*) contain information on 309 cadasters of the Zelivka watershed, e.g. distribution of human population in towns (>500 inhabitants) and villages or settlements (<500 inhabitants), sewerage, wastewater treatment and discharges, farm animals, and land use. Maps with localization of individual municipalities are also given (obcebo.\*, sildazelo.\*). The data are related to the period between 1991 to 2000.

Waste water discharges (CZZ\_WWTPSources.\*, CZZ\_AgriSources.\*, CZZ\_WWTPSources.\*, CZZ\_PointSources.\*, bodzdrojo.\*) include effluents from waste water treatment facilities (WWTP) and direct discharges into water courses. About 59% population is connected to WWTP. Twelve largest WWTP have been equipped with enhanced P and N removal technologies since the middle of 1990s. Large farm animal breeding facilities are also potential sources of stream water pollution. However, the manure and slurry in the Zelivka catchment are applied purely to farmland and nutrients from this source can get into watercourses only marginally when the surface runoff occurs at sites of surface storage of manure. The data on direct discharge sources are not official.

and represent number of inhabitants that can be considered as a potentially attached to direct discharges. Direct discharges are illegal but real. Approximately 50% of nutrient production from this type of source has been determined to enter streams in several studies, however, this percentage can be highly dependent on the source size and on the distance from recipient.

#### *2.1.5. Water management*

Water management data files (CZZ\_WaterManagement.\*, CZZ\_WaterManDrain2.\*, watrego.\*, meliofino.\*, CZZ\_WaterManStrategy.\*) include information on tile drainage of agricultural land and on operation of reservoirs.

The tile drainage systems have been built on almost 20% of agricultural land, mostly during the 1970s and 1980s. Almost no drainage systems have been built since 1990. The present efficiency of these systems is not known; the service life is usually stated to be ~20 years.

The reservoirs in the Zelivka watershed include storage hydropower reservoirs (Sedlice, Vresnik), water quality and flood protection pre-reservoirs (Trnavka, Nemcice) and the drinking water storage Zelivka Reservoir.

Sedlice and Vresnik are the storage reservoir and a leveling reservoir, respectively, for hydropower in the peaking regime. The system has been in function in since 1926. Water is lead from the Sedlice Reservoir via a gallery into the hydroelectric power plant situated upstream from the impoundment of the Vresnik Reservoir that serves for the leveling of discharge peaks. The river channel downstream from the Sedlice dam is dry down to the gallery outlet except for periods when the storage capacity of the Sedlice Reservoir is full and the flow high enough to exceed the capacity of the power plant. The power plant works in an irregular regime, which causes daily and sub-daily discharge fluctuations downstream from the Vresnik dam (see the flow data at Station 5000). Another function of this reservoir

system is nutrient and suspended solids retention to protect water quality in the Zelivka Reservoir. Average retention of total N and total P is about 5 and 25%, respectively. Most retention occurs in the Sedlice Reservoir because the Vresnik Reservoir has very short hydraulic retention time.

The main purpose of the Trnavka and Nemcice reservoirs is nutrient and suspended solids retention to protect water quality in the Zelivka Reservoir. Water surface level in these reservoirs is maintained at their full storage capacity. The character of flow downstream from their dams is not significantly changed in comparison with the inflow (there are exceptions during periods of water level manipulations due to operation needs at the dams; compare the flow data at Stations 4600 - 4800 and 500 - 700). Average retention of total N and total P is about 8 and 45%, respectively, in Trnavka Reservoir. Average retention of total N and total P is about 13 and 20%, respectively, in Nemcice Reservoir.

Zelivka Reservoir is designed as a several-years storage reservoir for the supply of water for the capital of the Czech Republic, Prague. Its other purposes are flood protection and flow augmentation in the Sazava River. The permanent, storage, and flood protection capacities of the reservoir are  $21 \times 10^6$ ,  $246 \times 10^6$ , and  $42 \times 10^6$  m<sup>3</sup>. The flood protection pool is uncontrollable.

Water can be released from the reservoir via a shaft spillway (capacity  $\sim 260$  m<sup>3</sup> s<sup>-1</sup>) or two bottom outlets (capacity  $2 \times 49$  m<sup>3</sup> s<sup>-1</sup>). Five withdrawal levels can be selected within the whole range of reservoir depth.

The minimum flow downstream from the dam is  $0.3$  m<sup>3</sup> s<sup>-1</sup>. It is composed from the seepage through the dam ( $\sim 0.05$  m<sup>3</sup> s<sup>-1</sup>) and washing water ( $0.25$  m<sup>3</sup> s<sup>-1</sup>) released from the waterworks via the Ryzmburk settling reservoir. The designed average withdrawal is  $5.4$  m<sup>3</sup> s<sup>-1</sup> with 99% dependability according to time. During the periods when the withdrawal approached this value (1985-1992) the water level was low and only minimum flow was maintained downstream from the dam. Since 1990 a steady decrease of withdrawal amount

has occurred and the reservoir operation regime turned to an annular storage type with the complete filling of the reservoir pool every winter and spring.

Water withdrawal from the Zelivka reservoir is used for drinking water production (~95%) and as process water (filter washing; ~5%). Drinking water is diverted from the catchment via a gallery towards Prague, process water is returned via the Ryzmburk settling reservoir to the Ryzmburk stream about 1 km above its outlet into the Zelivka River.

Operational data from Zelivka Reservoir are available since 1975 until 2002.

#### *2.1.6. Water quality monitoring*

Streams and water bodies in the watershed were sampled at 75 stations (ZEL\_Stations4-SWMeasures.xls). This sampling station network covered various types of landscape (forest, farmland, urban) and all main tributaries into the Zelivka Reservoir and its all pre-reservoirs. The time series of nutrient (P, N) concentrations in the main tributaries into the Zelivka Reservoir cover the period from 1975 to 2000.

Water composition and limnological data from the reservoirs have been collected since 1992 (ZEL\_Stations5-Reservoir.xls). Regular sampling in two-week to month intervals have been carried out in the Zelivka Reservoir at 8 stations in the longitudinal reservoir profile between the dam and upper reaches. Monitoring at the pre-reservoirs was carried out during 1995-2000.

## **2.2. The Rimov**

The geo-referenced GIS of the Rimov watershed is under development at present. The data that describe climate, hydrology, water management and water quality are given in attribute files with localization of sampling and measuringment stations in Fig. 3.

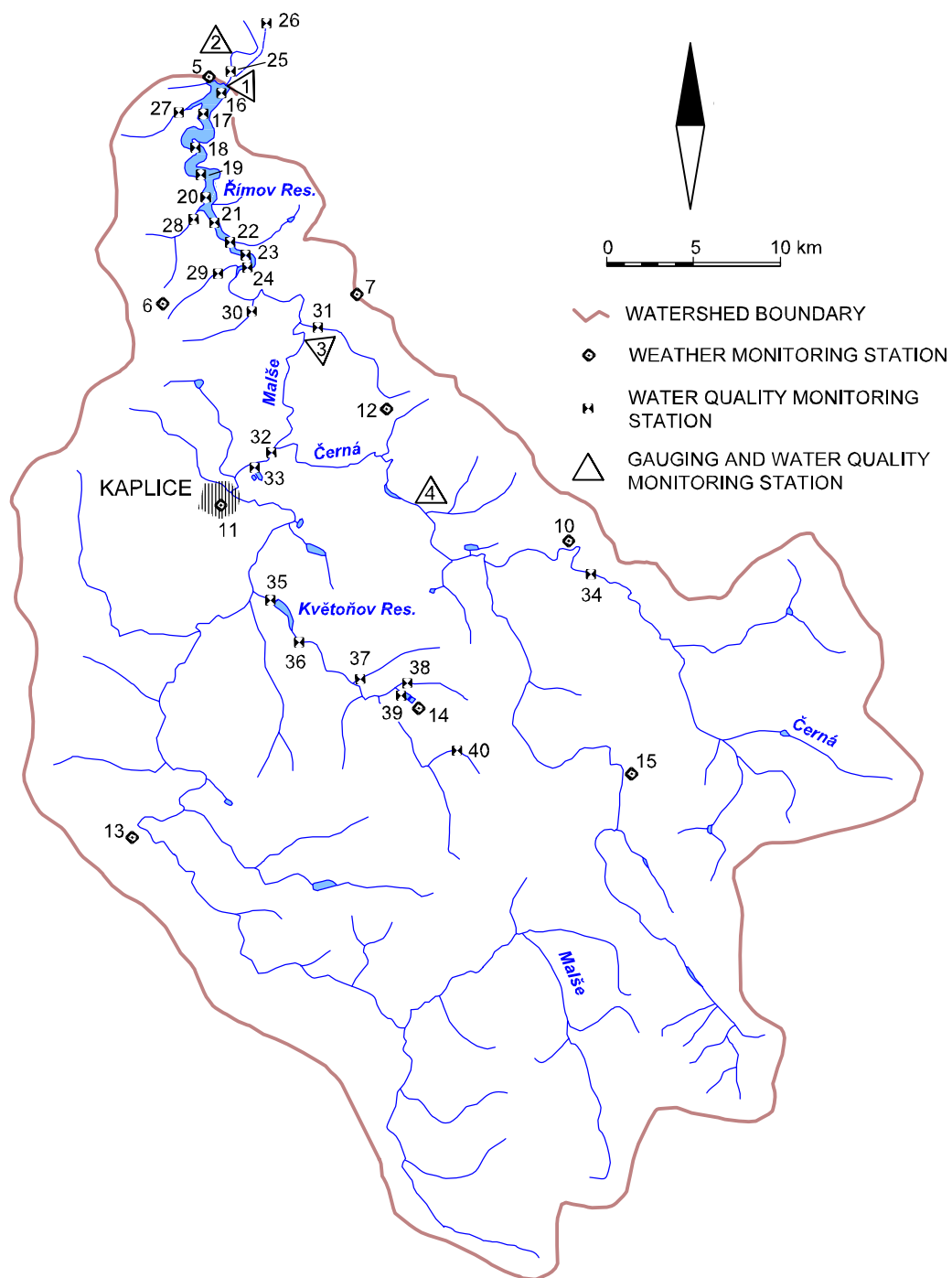


Figure 3. The Rimov Reservoir watershed with monitoring station localization

### *2.2.1. Climate*

The meteorological data are given in the attribute files named 'RIM\_Stations1-Weather.\*'. They consist of (i) long-term (1961-2002) records of daily precipitation at 8 stations across the watershed (Stations 6 to 15) and daily basic climatologic variables (temperature, air humidity, wind speed and direction, cloudiness) at 1 station that is located ~15 km in the northern direction from the Rimov dam (St. 9 – Ceske Budejovice) and (ii) several short-term data series from stations within the Rimov watershed (e.g. St. 5 Rimov Dam: 1983–1990, 1998-2000, 2003; St. 3 Malse Poresin: 1999-2002)

Bulk precipitation were collected at Station 5 (Rimov Dam) during the period between 1983 and 1903 to evaluate deposition rates of nutrients (P, N, C, S) and analyze ionic composition of precipitation. Original data are given in the attribute files 'RIM\_Stations1-Weather.\*' and their evaluation is published (Kopacek et al. 1997).

### *2.2.2. Hydrology*

The stream runoff data are given in the attribute files named 'RIM\_Stations3-SWFlow.\*'. A long-term data series of discharge have been monitored since 1931 in the Malse downstream from the Rimov Reservoir dam that was built in 1978; available daily data are from 1961. Shorter data periods of daily data are available from two stations in the watershed, i.e. Malse-Poresin (St. 3), 1979–2002, and Cerna-Licov (St. 4). Sub-daily data on discharge and water temperature are available at Malse-Poresin (St. 3) during 1998-2002.

### *2.2.3. Stream water quality monitoring*

The data on stream water composition are in the attribute files 'RIM\_Stations4-SWMeasures.\*'. A long-term data set for selected water quality variables (organic substances, nitrate, chloride, sulfate, phosphate, calcium) exists for Station 3 in 1979–2000

with daily or weekly sampling intervals. The evaluation of the daily data from this station on the concentration of organic substances were published recently (Hejzlar et al. 2003).

The other long-term data sets are related to the monitoring of the Rimov Reservoir and cover the period 1979–2002 with the three-week sampling intervals (St. 4 and 32).

Water composition in several small streams of the watershed were monitored in three-week intervals for one year (1996) to characterize runoff from areas with different land use (arable land, forest, mixed farmland and forest, urban; St. 35–40). The most important point source of pollution, i.e. the Kaplice Waste Water Treatment Plant (St. 33), has been monitored since 1985 in two-week or three-week intervals.

#### *2.2.4. Reservoir operation and water quality*

Data from the dam operation and from the monitoring of the reservoir limnology are in the files 'RIM\_Stations5-Reservoir.\*'.

The dam operation data set covers the whole period from the initial stages of the first reservoir filling in 1979 until 2002. Daily and sub-daily data on pool elevation, inflow, outflow from 7 outflow structures, water temperature, and precipitation are included.

Stratification of temperature, dissolved oxygen, pH, and alkalinity has been measured at the dam station (St. 16) in three-week intervals since 1980.

Water chemistry (ionic composition, particulate and dissolved forms of organic carbon, dissolved reactive Si, N-forms, dissolved reactive P, total P, chlorophyll-a) and water biology (phytoplankton, bacteria, zooplankton) have been monitored at the dam station (St. 16) in the surface layer in three-week intervals since 1980. Vertical and longitudinal patterns of water chemistry and biology were monitored in 1991, 1993, and 1999.



## 2.3. The Lipno

The geo-referenced GIS of the Lipno watershed is under development at present. The data describing climate, hydrology, water management and water quality are given in attribute files with localization of sampling and measuring stations in Figs. 4 and 5.

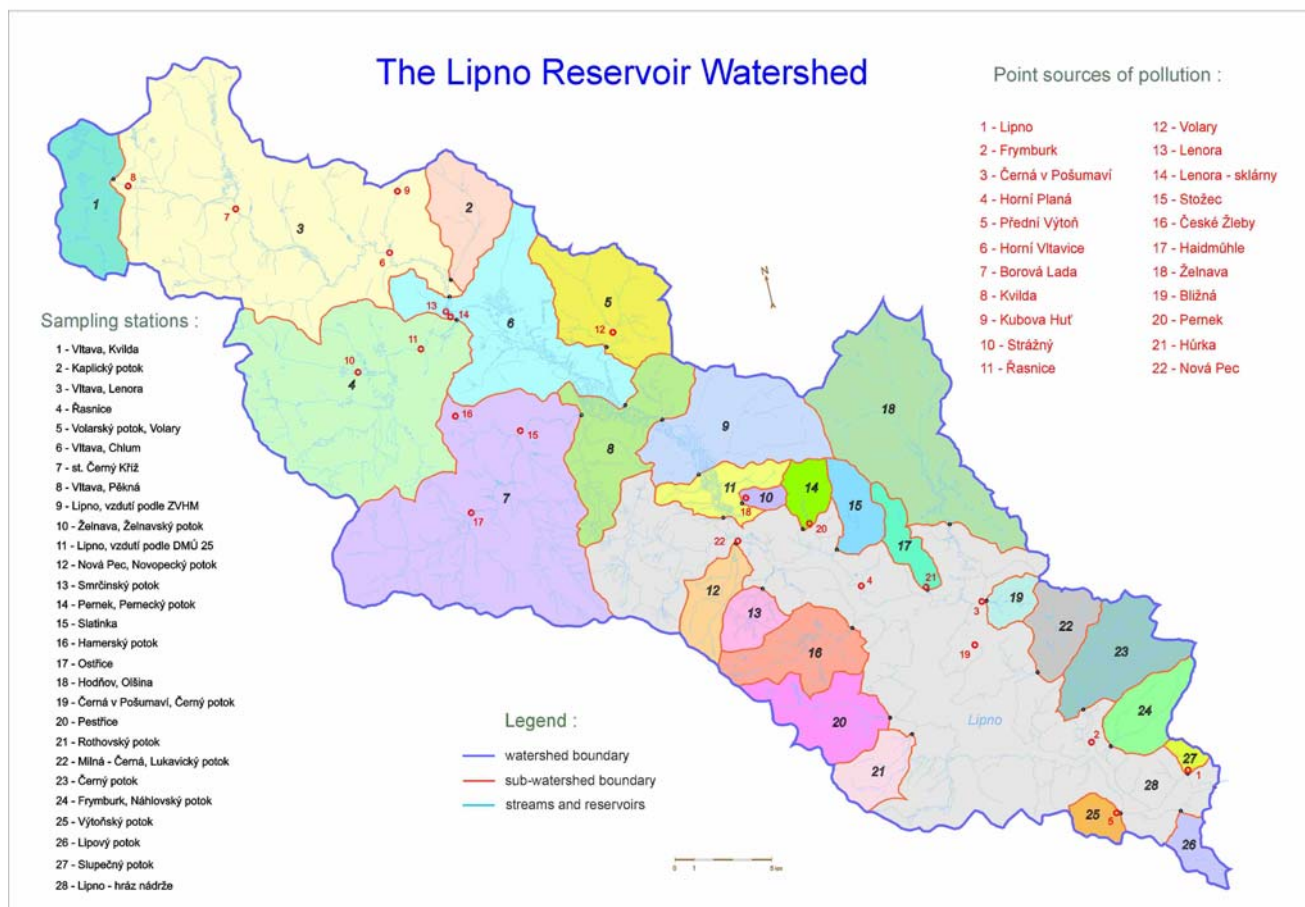


Figure 4. The Lipno Reservoir watershed with monitoring station localization

### 2.3.1. Climate

The meteorological data are given in the attribute files named 'LIP\_Stations1-Weather.\*'. They consist of daily data series (temperature, air humidity, wind speed and direction,

cloudiness) from three stations, i.e. St. 33, Cerna v Posumavi (1994-2002), St. 34, Nova Pec (1970-1993), and St. 32, Vyssi Brod (1961-1999; situated ~7 km southeast from the Lipno dam).

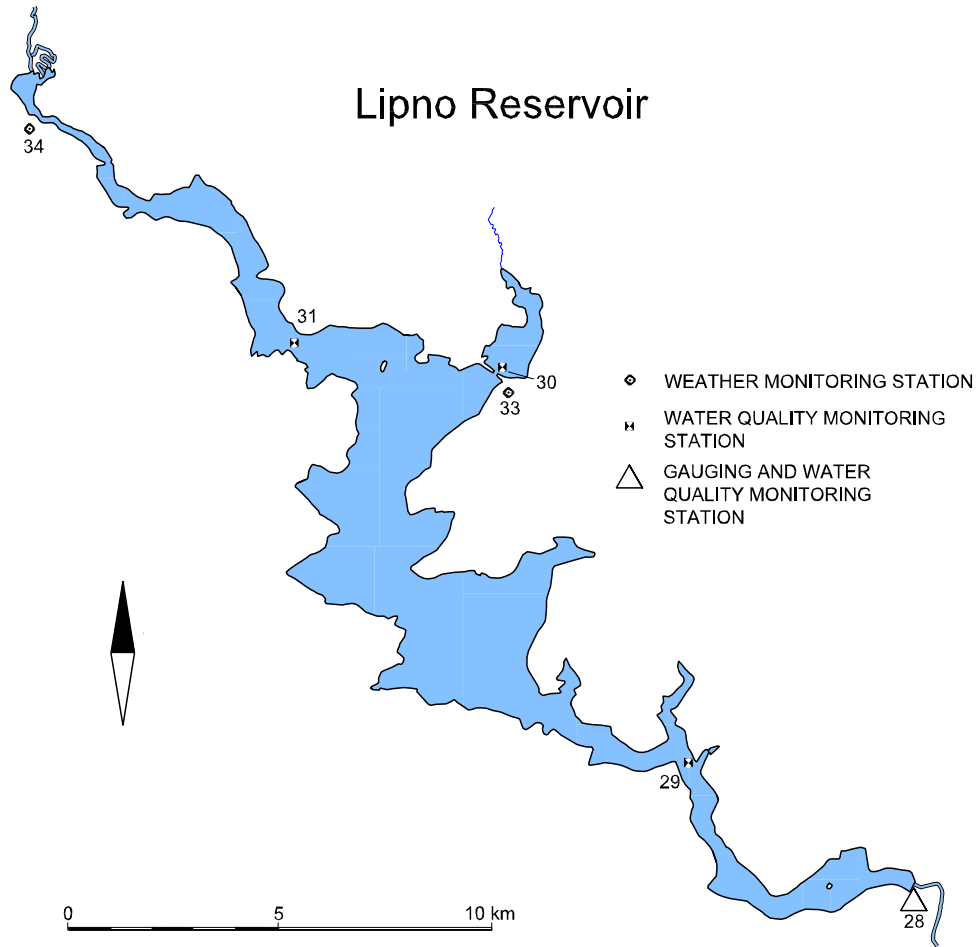


Figure 5. Lipno Reservoir with sampling and measuring station localization.

### 2.3.2. Hydrology

The stream runoff data are given in the attribute files named 'LIP\_Stations3-SWFlow.\*'. Long-term data series of discharge have been monitored since the 1950s along the Vltava River downstream and upstream from the Lipno Reservoir at several stations (St. 3, 6, 7, 8,

and 35 (Vyssi Brod)) by the Czech Hydrometeorological Institute, however, only data sets from St. 3 and 6 during 2000-2002 and St. 8 during 1998-2002 are available at present.

#### *2.3.3. Stream water quality monitoring*

The data on stream water composition in the Lipno watershed are in the attribute files 'LIP\_Stations4-SWMeasures.\*'. A long-term data set for selected water quality variables (organic substances, nitrate, chloride, sulfate, phosphate, calcium) exists for Station 8 in 1968–1969 and 1977–2002 with monthly sampling intervals. Water quality at Stations 1 to 27 have been monitored in month to three-month intervals since 1998 (organic substances, inorganic nitrogen forms, dissolved reactive P and total P).

#### *2.3.4. Reservoir operation and water quality*

Data from the dam operation and from the monitoring of the reservoir limnology are in the files 'LIP\_Stations5-Reservoir.\*'.

The dam operation data set covers the period between 1991 and 2002. Daily data on pool elevation, inflow, outflow, water temperature, and precipitation are included. The daily inflow data are scattered because of relatively imprecise measurement of water surface level of the reservoir pool.

Stratification of temperature, dissolved oxygen, pH, and alkalinity has been measured at the dam station (St. 28) in two-week to month intervals in 1964–1968 and 1994.

Water chemistry (organic substances, inorganic nitrogen forms, dissolved reactive P, total P, chlorophyll-a) and water biology (phytoplankton, bacteria, zooplankton) have been monitored at the dam station (St. 28) in the surface layer in month intervals since 1991 and at Stations 29, 30 and 31 during 2000–2002. Vertical and longitudinal patterns of water chemistry and biology were monitored in 1991 and 1994.

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